



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
166 Water Street
Woods Hole, MA 02543

V

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CRUISE RESULTS

NOAA FRV DELAWARE II
Cruise No. DE 97-08
Bioacoustic Study

CRUISE PERIOD AND AREA

The cruise was divided into three parts. Part I began with the FRV Delaware II departing Woods Hole at 19:00 on 22 July 1997. Midwater trawl testing was completed east of Cape Cod around 41°43'N 69°36'W and calibration of the EK500 echo-integration system was completed at 41°45'N 70°15'W (Fig. 1). The FRV Delaware II arrived into Portland, ME at 7 am on July 27 to exchange scientific staff and to contract work on the Furuno omni-directional sonar system.

Part II began upon departure from Portland, ME at 8 PM on July 28. A systematic midwater survey using the FRV Delaware's recently installed sonar, echo-integrator, and trawl monitoring systems was completed outside of Portland along Jeffreys Ledge (centered around 43°00'N 73°00'W, Fig. 1) during July 29 through July 31. The FRV Delaware II arrived in Portland at 07:00 on August 1 to exchange scientific staff.

Part III began departing from Portland at 14:00 on August 2. The integrated midwater trawling and acoustical survey was extended to the Fippennies Ledge region (Fig. 1). When herring aggregations were located, an *in-situ* target strength (TS) experiment was done during the last 3 days on Fippennies Ledge (Fig. 2). An unplanned portcall was made into Portland, ME on August 5 to pickup an hydraulic engineer to examine the trawl winches. The cruise was completed upon the FRV DELAWARE's arrival into Woods Hole at 07:00 on August 8, 1997.

OBJECTIVES

Each of the 3 parts of the cruise had different objectives. The objectives of Part I were to; (1) test and evaluate a recently purchased midwater trawl (Gourock design 42625SH Quantum) with the assistance from David King (Midwater Trawl Specialist from the AKFSC, Seattle, Washington), (2) tune the midwater trawl performance using the DELAWARE's new Simrad FS903 and ITI trawl monitoring systems, (3) train the DELAWARE's officers, crew, and scientists in midwater trawling operations by Dave King, (4) calibrate the FRV DELAWARE's recently installed haul-mounted split-beam 38 and 120 kHz transducers of the Simrad EK500 echo-integration system.



The objectives of Part II were to; (5) modify and evaluate the FRV DELAWARE's new Furuno omni-directional scanning sonar for quantitative fish survey applications, (6) obtain training from Gary Melvin (Canadian Depart. Fisheries and Oceans, St. Andrews Biological Station) in sonar operations for surveying herring, (7) conduct a pelagic fish survey using the omni-directional sonar, multifrequency EK500 echo-integration system, and midwater trawl, (8) locate herring aggregations for an *in-situ* TS experiment during Part III, (9) develop an awareness and encourage collaboration among fisheries biologists from various agencies who are concerned with developing field studies in fisheries acoustic research.

The objectives of Part III were to; (10) calibrate the 12 kHz single-beam transducer of the EK500, (11) conduct EK500 noise tests to define optimal survey speeds and potential acoustical interference, (12) continue with the pelagic fish survey operations using sonar, echo-integration, and midwater trawling to locate herring aggregations in study area, (13) conduct an *in-situ* multifrequency TS experiment using the EK500 echo-integrator, midwater trawling, Methot sampler, CTD, and underwater camera to ground-truth EK500 data, and (14) training from and collaboration with David Demer (SWFSC, LaJolla, CA) in multifrequency signal processing to determine TS distributions of Atlantic herring during the *in-situ* experiment.

METHODS

The cruise was conducted in three parts; midwater trawling and EK500 calibrations during part I, sonar operations during part II, and additional EK500 calibrations during part III. During the last few days of part III, an *in-situ* acoustic TS experiment was conducted to ground-truth the EK500.

Operations began with the deployment and testing of a recently purchased Gourock (series 42625SH Quantum) midwater trawl rigged with Gourock 4 m² Morgere 'W' Vertical doors. This midwater trawl is a four seam design with 332 foot headrope, footrope, and breastlines (Fig. 3). The trawl has 42 foot mesh (stretched) in the wings, and tapers back to 4 inch mesh in the cod-end. The cod-end was lined with ¼ inch mesh (#147 knotless nylon). The trawl was rigged with 240 foot upper and lower bridles (Fig. 4). Approximately 500 lb of tomweight was used on each lower setback. The doors were rigged for maximum spread. The original rigging was slightly modified with additional hardware (8-ton ball-bearing swivels, G-hooks, flat links) (Fig. 5). The Gourock midwater trawl was towed at the FRV DELAWARE's maximum speed resulting in tow speeds of 3.5-4.0 knots. During survey operations, the midwater trawl was towed at an average speed of 3.7 knots for 30 minute duration.

The performance of Gourock midwater trawl was measured using two recently installed Simrad trawl monitoring systems; a wireless ITI system and a third-wire FS903 system. The ITI system has a fixed haul triple transducer which communicates acoustically to an array of ITI sensors. ITI Temperature/Depth and Height sensors were attached to the headrope and ITI Spreader #2 sensors were attached to the trawl wings. Brackets were welded to the midwater doors for attaching the ITI Spreader #1 sensors. The FS903 system is a sector scan sonar which provides an acoustical image of the trawl opening. The FS903 sonar housing is attached to the trawl's headrope, and communicates to the FRV DELAWARE via a third-wire constant tension winch system.

The ITI system was integrated with the EK500 echo-integrator to provide trawl lines on the EK500 echograms and EK500 bottom depth on the ITI display.

After the trawl tests were completed, the recently installed EK500 haul-mounted 38 and 120 kHz split-beam transducers were calibrated in Cape Cod Bay during part I. The FRV DELAWARE was anchored from the bow due to high winds, and the 38 and 120 kHz calibration spheres were simultaneously lowered under the haul by three monofilament lines. Three remotely controlled downriggers positioned around the haul were used to raise and lower the monofilament lines to center and move the calibration spheres within the acoustical beam. Simrad 60 mm (-33.6 dB for 38 kHz) and 23 mm (-40.4 for 120 kHz) copper spheres were used for calibrating the EK500 echo-integration system. The 60 mm sphere was centered 15.0 m below the transducers, while the 23 mm sphere was 10.5 m below. During the calibration, a constant value of 1480 m/s was used for the sound speed in sea water. Simrad's Lobe program (ver.95.01.17) was used to calculate the TS gain, 3 dB beam angles, and mechanical offset angles of the transducers. The S_v transducer gain was then calibrated using the integration tables.

Additional EK500 calibrations were completed in the beginning of part III. A CTD cast (CTD#1) was completed to calculate the sound velocity by depth based on the salinity and temperature profiles. Calibrations of the 38 and 120 kHz transducers were completed using the derived sound velocity profile. The single-beam 12 kHz transducer was also successfully calibrated using a standard 45 mm copper sphere. The 38 kHz split-beam transducer was used to direct the 45 mm sphere towards the center of the 12 kHz single-beam transducer at a depth of about 35-40 m. Noise tests were also completed with the EK500 to identify potential acoustical interference with the FRV DELAWARE's various acoustical instrumentation.

The EK500 echo-integrator was operated continuously during parts II and III. Acoustical data from its three frequencies (12, 38, and 120 kHz) were collected simultaneously at a pulse length of about 1.0 m/s (short, medium, and long, respectively). The EK500 transducer depth setting was set to 3.2 m for the FRV DELAWARE during survey operations.

The FRV DELAWARE's newly installed Furuno CSH-5 omni-directional scanning sonar was used to locate herring aggregations during parts II and III. Default settings were used during the sonar operations. Since herring are known to be close to the surface during the summer, the tilt angle was adjusted as close to the surface as possible with minimal surface interference (about 7°-10° from the surface). The cone-shaped receiving beam has a vertical beam width of 15° resulting and a search radius of up to 1800 m. The search radius was generally set to 150-400 m in depths of 70-200 m.

The Furuno sonar system had no ports for digital output, therefore a contractor was hired during a portcall in Portland, ME to temporarily rig the sonar system with a video card for analog data output. Video images and navigational data were captured every three minutes during fish searching operations. These data will be used later to further evaluate the application of the omni-directional sonar for fish assessment.

A 5 m² Methot sampler was used to collect macro-invertebrates during the *in-situ* TS experiment that potentially contribute significant acoustical backscatter (Fig. 6). The Methot was fitted an inner 1 x 2 mm oval mesh net. An outer bag was also used for additional support. Two flowmeters were suspended in the mouth opening for deriving volume filtered estimates. The Methot was fished double-obliquely from surface to within 4 m from the bottom and back (tow-yo) at a constant ship speed of 2.0-2.5 knots. Its depth-temperature profile was monitored in realtime using a Simrad ITI Depth-Temperature sensor attached to the bottom of the Methot frame.

An underwater camera (Deep-Sea Power & Light MicroSea 1050) was used to directly verify acoustical targets. The MicroSea 1050 video camera has a low light (0.05 lux) auto adjusting iris with a 77° horizontal and 59° vertical field. The camera has a 2000 m depth capability. The camera and two lights (with 150 W bulbs) were mounted in a simple pipe-like tow-body which was lowered beneath the vessel while drifting. The camera and lights were powered by 12 v and 110 v, respectively. Video deployments were limited to depths of about 75-80 m because the power cables were only 100 m in length. The underwater video observations were recorded on S-VHS video tapes.

SeaBird CTD (conductivity-temperature-depth) profiles were taken at each station. A temperature-depth minilog probe has also attached to most of the camera, CTD, Methot, and midwater trawl hauls to confirmed temperature-depth profiles. Continuous navigational, hydrographic, and meteorological data were collected by the FRV DELAWARE's Scientific Computer System (SCS).

Biological samples and data from the midwater trawl and Methot catches were processed at sea. Fish and invertebrates were identified to species, weighed, counted, and recorded on standard NEFSC logsheets. Fork length (mm), total length (mm), and individual weight (0.1 g) were measured for Atlantic herring. Stomach contents of herring were weighed (0.1 g) and prey identified to species at sea. Other fish were measured by fork length (cm). Selected invertebrates (euphausiids, shrimp, and ctenophores) were also measured (mm) and weighed to the nearest (0.1 g). Shrimp and euphausiids were measured from the tip of the telson to the front of the eye.

Preliminary post-processing of the EK500 data was completed at sea using the Simrad BI500 post-processing software on a Sparc-10 workstation. David Demer (from the SWFSC, LaJolla, CA) completed the preliminary multifrequency analysis of TS (target strength) distributions for herring at sea using three filters; minimum and maximum duration of echo envelope, minimum TS and maximum B, and maximum sample-to-sample deviation of phase measurements. The multifrequency (12, 38, and 120 kHz) data collected by the EK500 will be used to develop new target rejection algorithms for defining the acoustic TS distributions of Atlantic herring and other important scatters (e.g., euphausiids, shrimp, and ctenophores) observed during the bioacoustic study.

RESULTS

Training was provided by Dave King (AKFSC) with the Gourock midwater trawl operations. Slight modifications were made to the trawl's hardware (Fig. 5). Eight-ton ball-bearing swivels were particularly important to eliminate twists in the trawl resulting from the new trawl wires. During the cruise, a portcall was made to Portland, ME to

resolve twists in the trawl and purchase additional swivels. The trawl was generally deployed and set in roughly 40 minutes, as long as the trawl was on the net reel without twists or slack. It was critical that the trawl went on the net reel straight to ensure a relatively quick set during the following haul. It is strongly recommended that a midwater trawl be laid out, adequately marked, and bundled without twists before and after each cruise.

The major problem with the midwater trawl operations was that the trawl could not be fished to its intended speed of 5.0 knots. The Gourock midwater trawl was originally designed to be towed at 5.0-5.5 knots by a 500 hp vessel, however heavier material was used in its construction from the original design. The midwater trawl was towed at the FRV DELAWARE's (rated at 1200 hp) maximum tow speed resulting in a towing speed of 3.5-4.0 knots. During survey operations, the midwater trawl could only be towed at about 3.7 knots.

The Simrad ITI trawl monitoring system provided measurements of the midwater trawl's performance (Fig. 7 and 8). The maximum speed that the Gourock midwater trawl could be towed by the FRV DELAWARE II was 4.0 knots, although 3.7 knots was considered to be the FRV DELAWARE's maximum sustained towing speed for this trawl. The mouth opening of the trawl averaged 25 m horizontal and 18 m vertical. The trawl tow profile responded quickly to slight changes in ship speed. The minimum tow speed was appeared to be 3.5 knots at which the midwater trawl doors seem to become unstable and drop, particularly when towing with the wind/swell (Fig. 8).

The Simrad FS903 trawl monitoring system malfunctioned due to seawater linkage in housing. Spare FS903 parts were not available until the end of the cruise. Third-wire winch problems also prevented the use of the FS903 system. Trawl performance measurements relied on the ITI readings, however the response time delay of the ITI ranged from 1-3 minutes. The faster and more reliable response time of the FS903 was considered critical when midwater trawling in regions of uneven bottom topography. During one haul, the bottom raised abruptly resulting in the trawl hitting bottom. This could have been prevented with improved response time from the bridge by installing a second ITI monitor at the helm and an intercom between the winch room and bridge. It is also recommended that spare parts of all the ship's electronics be available during each cruise.

The Furuno CSH-5 omni-directional scanning sonar was used during part II and III to locate herring aggregations in the Gulf of Maine. The cone-shaped beam of the sonar provided a search radius around the vessel ranging 150-800 m. The sonar display provided both the horizontal field and a vertical profile of its cone-shaped receiving beam (Fig. 9). The sonar proved to be a valuable tool for locating herring shoals. The sonar was also used to track the diurnal distributional patterns of herring aggregations on Fippennies Ledge. The herring appeared to form large dense schools on Fippennies Ledge near the surface during the night (Fig. 9). At dawn, most of the herring concentrations moved off the ledge into deeper water, descended to near bottom, and dispersed.

The Furuno CSH-5 sonar interfered acoustically with the Simrad EK500 echo-integration. Therefore, the sonar and EK500 could not be used simultaneously until the

interference problem is resolved. The best solution is to obtain a Simrad sonar system which can be integrated with the existing EK500 echo-integrator and ITI trawl monitoring systems. Another solution is to synchronize the Furuno sonar's ping rate with the EK500. It is highly desirable to conduct an acoustical fish surveys using the EK500 and sonar simultaneously to (1) minimize the problem of fish avoidance from vessel noise (a problem in depths less than 200 m), (2) enhance search ability for pelagic fish aggregations, and (3) detect fish concentration near surface that can not be detected by echo-integration. Another major limitation of the omni-directional sonar was its lack of digital output. This problem was marginally resolved by the Femto contractor who successfully rigged the sonar with a video capture board to obtain images that were merged with SCS navigational data at a rate of every three minutes (Fig. 9). The contractor will provide software to analysis and evaluate the sonar data for fish assessment applications after the cruise.

A combination of sampling operations including sonar, EK500 echo-integration, midwater trawl, Methot sampler, CTD, and underwater camera/video were used to conduct the *in-situ* acoustical TS experiment during part III of the cruise. An event log and station data are provided in Table 1. Sonar was used only to locate herring aggregations, and was turned off during the TS data collection by the EK500. The EK500 collected acoustical data continuously from its three frequencies (12, 38, 120 kHz). Sampling was replicated to define the dawn, day, dusk, and night distributional patterns in backscatter along an experimental transect extending on Fippennies Ledge (70 m), southward to its slope, and into deepwater (200 m) (Fig. 10). Fixed gear on the ledge restricted the Methot and midwater trawling to the slope and deepwater sites.

Atlantic herring were the dominant species captured by the midwater trawl, and euphausiids (*Megacanthiphanes norvegica*) and ctenophores were the dominant invertebrates sampled by the Methot sampler (Table 2). The herring ranged in fork length (FL) from 200-300 mm with an average of 232 mm, however the herring FL distribution was bimodal (Fig 11). Since TS-length regressions are typically determined from total length (TL), the individual FL and TL were measured at sea (Fig 12). Furthermore, the TS-length relationship may not be linear, but rather more of a function of body weight. Therefore, the relationship between individual body weights and lengths were also derived from at sea measurements (Fig. 12). Length frequencies for *M. norvegica* and Ctenophores were also determined from at sea measurements (Fig. 13 and 14).

The analysis of fish stomach contents at sea revealed that herring (n=52) on Fippennies Ledge were feeding predominantly on the euphausiid *M. norvegica*. Underwater video observations were made on herring feeding on euphausiids at night.

The underwater video system was deployed under the vessel while drifting to verify backscatter and observe herring schools. The herring behavior did not appear disturbed by the video camera or its lights, and their feeding behavior were often observed at night. Herring were generally spaced about 1-2 body lengths apart within their schools. Blue sharks were occasionally observed feeding on the herring schools. The underwater camera proved to be a useful approach for directly verifying some acoustical targets like herring. However, other types of backscatter like euphausiids avoided the camera lights. This was demonstrated by the dispersion of the

euphausiids when the camera and its lights were lowered into their scattering layer. When the camera lights were turned off, the euphausiid swarms returned only to be seen when the lights were turned back on.

The underwater camera system provided the only means of verifying acoustical targets on the ledge because the midwater trawl and Methot sampler could not be deployed among the fixed gear along the ledge. The camera deployment was limited by its 100 m power cable, therefore backscatter below 70-80 m could not be observed. The underwater camera systems needs further modifications; a longer armored power cable, a portable winch with slip-rings, lasers for measuring targets, and angle indicator to determine fish orientation which affects TS measurements. Infra-red or SIT cameras are other considerations for future bioacoustic studies to minimize avoidance.

Echo-integration data were collected from three frequencies (12, 38, 120 kHz) simultaneously using the Simrad EK500 Scientific Sounder. Calibration of the transducers was successfully completed with a high degree of precision (Lobe RMS ranged from 0.25 - 0.35 dB). The remotely controlled downriggers used for the EK500 calibration dramatically increased its precision and reduced calibration time. Post-processing of the EK500 data was partially completed at sea using the Simrad BI500 software on a Sparc-10 workstation. Single frequency filtering of the 38 and 120 kHz resulted in bimodal TS distributions (Fig. 14). Herring contributed to the higher TS values (around -40 dB for 38 kHz) due to their swimbladder, while the low level backscatter (around -60 dB for the 38 kHz) resulted mostly from euphausiids and possibly ctenophores (Fig 14). The multifrequency target rejection technique provided better defined TS distributions showing herring TS between -45 dB and -30 dB, while euphausiids seem to range between -60 dB and -50 dB (Fig. 15). The herring TS distribution had some agreement with their bimodal length distribution (Fig. 11).

DISPOSITION OF DATA

Acoustical, biological, and hydrographic will be analyzed and archived at the NEFSC, Woods Hole MA. Multifrequency signal processing will be completed in collaboration with staff at the SWFSC, LaJolla, CA.

SCIENTIFIC PERSONNEL

National Marine Fisheries Service, NEFSC, Woods Hole, MA

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Kevin Friedland	Research Fisheries Biologist	II
William Overholtz	Research Fisheries Biologist	II
Rodney Rountree	Research Fisheries Biologist	II
Jewel Parham	Biological Laboratory Technician	II
Vaughn Silva	Biological Laboratory Technician	I
Richard Yetter	Biological Laboratory Technician	I, II, III
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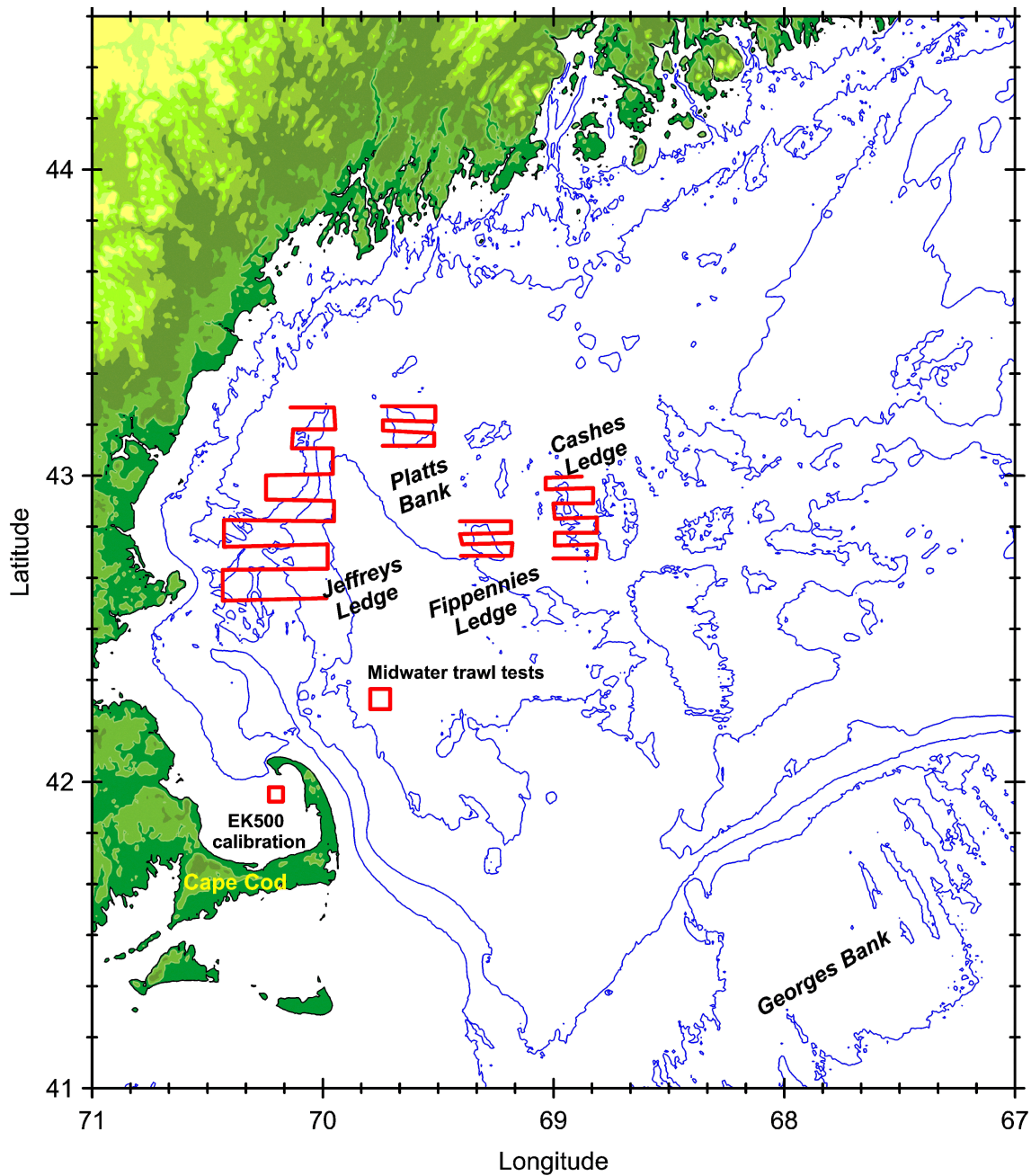


Figure 1. Midwater trawl testing and EK500 calibrations occurred near Cape Cod during the first part (July 22-27, 1997) of the NOAA cruise DE 97-08. Bioacoustic surveys were completed in the Gulf of Maine on Jeffreys Ledge, Cashes Ledge, Platts Bank, and Fippennies Ledge during the second phase of the cruise (July 28-August 1). An *in-situ* acoustic TS (target strength) experiment was completed on Fippennies Ledge during part III (August 2-7).

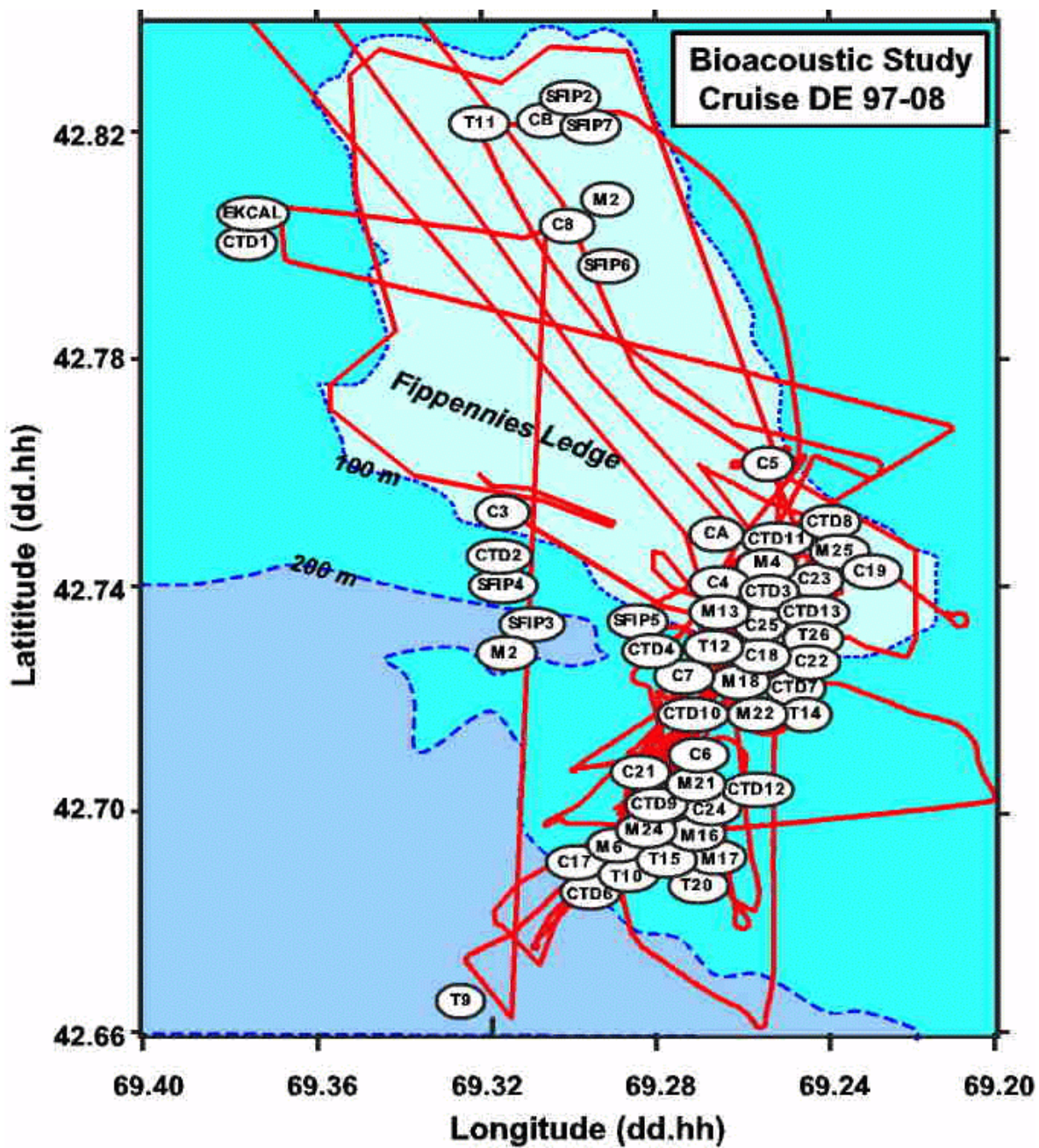


Figure 2. Station locations in the Fippennies Ledge region during the *in-situ* acoustic TS experiment on NOAA cruise DE 97-08 on August 2-7, 1997. The first character(s) of the station designation indicates the gear deployed (T# = midwater trawl, M# = Methot, CTD# = CTD profile, C# = Camera, S# = sonar, EK# = EK500 calibration).

Figure 3. Specifications of the Gourock midwater trawl (series 42625SH Quantum) used during the bioacoustic cruise DE 97-08 during July 22 - August 8, 1997.

Figure 4. Specifications of the bridle rigging for Gourock midwater trawl (series 42625SH Quantum) used during the bioacoustic cruise DE 97-08 during July 22 - August 8, 1997.

Figure 5. Hardware modifications to the Gourock midwater trawl (series 42625SH Quantum) rigging during the bioacoustic cruise DE 97-08 during July 22 - August 8, 1997. Ball-bearing swivels were added to eliminate twisting, while other hardware provided easier hook-up on deck.

Figure 6. Diagram of the 5 m² Methot sampler used during the bioacoustic cruise DE 97-08. The squared frame of the Methot provides a mouth opening of 5 m².

Figure 7. ITI trawl measurements during performance testing of the Gourock midwater trawl (series 42625SH Quantum) during the bioacoustic cruise DE 97-08. This test haul was conducted into the wind/swell. The maximum tow speed of the FRV DELAWARE II (rated at 1200 hp) for this trawl was 4.0 knots.

Figure 8. ITI trawl measurements during performance testing of the Gourock midwater trawl (series 42625SH Quantum) during the bioacoustic cruise DE 97-08. This test haul was conducted with the wind/swell. The maximum tow speed of the FRV DELAWARE II (rated at 1200 hp) for this trawl was 4.0 knots. The trawl doors became unstable at 3.5 knots at which the trawl would not stay in the water column.

Figure 9. Example of a digital image from the Furuno CSH-5 omni-directional sonar showing the horizontal field (range of 200 m) and vertical profile. A herring school approximately 70 m across (most of which are in the upper half of the water column) is located about 15° from the ship's heading during the FRV DELAWARE's search operations on Fippennies Ledge.

Figure 10. An example of dawn, day, dusk, and night acoustical transects with various gear deployments during the *in-situ* TS experiment in the Fippennies Ledge region during part III of the bioacoustic cruise DE 97-08.

Figure 11. Length frequency of Atlantic herring captured by the Gourock midwater trawl during part III of the bioacoustic cruise DE 97-08.

Figure 12. Individual measurements of fork length, total length, and weight for Atlantic herring captured during part III of the bioacoustic cruise DE 97-08.

Figure 13. Length frequency of the euphausiid *Meganctiphanes norvegica* captured by the Methot sampler during part III of the bioacoustic cruise DE 97-08. Euphausiid lengths were measured from the tip of the telson to the front of the eye.

Figure 14. Length frequency of the ctenophores captured by the Methot sampler during part III of the bioacoustic cruise DE 97-08.

Figure 15. Preliminary target strength (TS) distributions for the EK500's 38 and 120 kHz frequencies after single frequency target rejection from the cruise Bioacoustic Study, cruise DE 97-08.

Figure 16. Preliminary target strength (TS) distributions for the EK500's 38 and 120 kHz frequencies after multi-frequency target rejection from the Bioacoustic Study, cruise DE 97-08.

Table 1. Event log and station data for the in-situ TS experiment during part III of the bioacoustic cruise DE 97-08.